Description

METHOD AND APPARATUS FOR PROVIDING A SIMULATION OF A
WELDING PROCESS USING INTEGRATED MODELS

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This application claims the benefit of prior
provisional patent application Serial No. 60/161,816
filed October 27, 1999.

10 Technical Field

This invention relates generally to a method
and apparatus for modeling a welding process and, more
particularly, to a method and apparatus for
integrating models for a welding process to perform a
15 thermal and structural analysis of the process.

Background Art

The process of welding materials has some
amount of detrimental effect on the materials being
20 welded. For example, materials being welded are
subjected to residual stresses and distortions due to
the extreme heat caused by the weld process.

In the past, attempts have been made to
analyze and determine the effects of heat on materials
25 from the welding process. One method in particular,
the finite element method (FEM), uses finite element
analysis to model the weld process, and has been
widely used to analyze the thermal effects of welding.
However, FEM can be extremely cumbersome to implement
30 and very costly.

Another method used to determine the effects of heat on materials from the welding process incorporates an analytical solution to determine the thermal history of the welding process. For example,

5   analytical solutions have been developed which use the superposition of point heat source solutions. These methods generally do not require the extremely cumbersome finite element analysis techniques previously used, and therefore provide a much more

10   rapid analytical solution procedure. However, analytical methods do not account for such features as weld joint geometry. Furthermore, it may be desired to use both types of thermal models for some applications. For example, an analytical based model

15   may be used for providing rapid, global solutions, and the FEM may be used to provide accurate temperature models for local areas of concern.

The present invention is directed to overcoming one or more of the problems as set forth

20   above.

Disclosure of the Invention

In one aspect of the present invention a method for providing a simulation of a welding process

25   using integrated models is disclosed. The method includes the steps of determining a model of a geometry of a set of materials to be welded, defining a set of coordinates of elements and nodes of the geometry model for a finite element analysis mesh,

30   delivering the finite element analysis mesh

coordinates to a thermal analysis model, the thermal
analysis model including an analytical solution model
and a finite element analysis model, and determining a
thermal analysis of the welding process, the thermal

5   analysis responsively providing a thermal history of
the welding process. The method further includes the
steps of delivering the thermal history of the welding
process to a structural analysis model, and providing
a structural analysis of the welding process as a

10   function of the thermal history.

Brief Description of the Drawings

Fig. 1 is a block diagram illustrating a
preferred embodiment of the present invention; and

15   Fig. 2 is a flow diagram illustrating a
preferred method of the present invention.

Best Mode for Carrying Out the Invention

Referring to Fig. 1, a block diagram

20   illustrating a preferred embodiment of a set of
integrated models 100 for performing a simulation
analysis of a welding process is shown. The
integrated models 100 work together to determine
stresses and distortions of a material which is welded

25   in the welding process. The stresses and distortions
have an adverse effect on the strengths and
characteristics of the material. Therefore, it is
desired to model the stresses and distortions, and use
the information from the models to determine methods

30   which may minimize the adverse effects of welding.

In the preferred embodiment, an
interconnection tool 114, such as a graphical user
interface (GUI), interconnects the models into an
integrated network of working models to determine

5   stresses and distortions of the material. The
interconnection tool 114 is preferably computer-based
and may be configured to operate autonomously, through
manual intervention, or some combination of the two
modes. For example, the interconnection tool 114 may

10   coordinate the modeling functions while displaying the
status and results to a human, who may override the
system or input additional information at any desired
time.

A geometry modeler 102 determines the

15   geometry model for the materials to be welded.
Preferably, the geometry modeler 102 simplifies the
geometry by removing unnecessary features of the
materials from the model. Examples of such features
include, but are not limited to, chamfers, holes,

20   slight irregularities, and the like.

The geometry model data is then delivered to
a meshing tool 104. The meshing tool 104 is used to
generate a finite element analysis mesh, preferably by
defining coordinates for elements and nodes which

25   constitute the mesh. Finite element analysis
techniques which use mesh coordinates are well known
in the art and will not be described further.

A thermal analysis model 106 is used to
perform a thermal analysis of the materials during the

30   welding process. In the preferred embodiment, the

thermal analysis model 106 includes at least two
models. An analytical solution model 108 provides a
rapid analytical solution of the thermal process,
i.e., welding process, for a global solution of

5   distortions caused by the welding process. A finite
element analysis model 110 provides local detailed
analysis of residual stress from the welding process.

     In the preferred embodiment, the analytical
solution model 108 determines solutions of point heat

10   sources, the point heat sources being obtained from
heat input based on welding processes and reflected
heat sources determined from adiabatic boundary
conditions of the material. The total analytical
solution is determined from superposition of all the

15   point heat sources. The principle of obtaining
reflected heat sources from adiabatic boundary
conditions is well known in the art and will not be
discussed further. The analytical solution model 108
provides a rapid solution for the complete welding

20   process. However, the solution is not highly
detailed. Therefore, the analytical solution model
108 is typically used when a fast, global solution is
desired, and a high degree of detail is not needed.

     The finite element analysis model 110

25   employs numerical computations of conditions at each
of the desired node and element coordinates of the
finite element analysis mesh. The finite element
analysis model tends to be computationally lengthy and
intensive. Therefore, the finite element analysis

30   model 110 is generally used only when a detailed

analysis of a specific portion of the model is desired.

The information from the thermal analysis model 106 is compiled into a thermal history and delivered to a structural analysis model 112. In addition, the finite element mesh provided by the meshing tool 104 is delivered to the structural analysis model 112. The interconnection is automatically established in the interconnection tool 114. In the preferred embodiment, the thermal history is delivered from the thermal analysis model 106 to the structural analysis model 112 by way of an interface module 116. Preferably, the interface module 116 is automated from the interconnection tool 114 and is adapted to seamlessly connect the thermal solution from the analytical solution model 108, the finite element analysis model 110, or both, to the structural analysis model 112.

The structural analysis model 112 provides further analysis of the materials during the welding process. Typically, the behavior of the material during welding is analyzed and modeled. Examples of features analyzed include, but are not limited to, melting and remelting of the material, phase transformation of the material, cyclic effects of multiple weld passes, and the like. The stresses and distortions of the material are determined by the structural analysis model. Preferably, the determined stresses and distortions may be further analyzed and subsequently used to modify the welding process to

reduce the adverse effects of the extreme heat
associated with welding.

5   Industrial Applicability

As an example of an application of the
present invention, reference is made to Fig. 2, a flow
diagram illustrating a preferred method of the present
invention.

10   In a first control block 202, a model of the
geometry of a set of materials to be welded is
determined. In a second control block 204, a set of
coordinates of elements and nodes of the geometry
model is defined for a finite element analysis mesh.

15   In a third control block 206, the finite element
analysis mesh coordinates are delivered to a thermal
analysis model 106. In the preferred embodiment, the
thermal analysis model 106 includes an analytical
solution model 108 and a finite element analysis model

20   110.

In a fourth control block 208, a thermal
analysis of the welding process is determined as a
function of at least one of the analytical solution
model 108 and the finite element analysis model 110.

25   The thermal analysis preferably provides a thermal
history of the welding process. In a fifth control
block 210, the thermal history of the welding process
is delivered to a structural analysis model 112. In a
sixth control block 212, a structural analysis of the

30   welding process as a function of the thermal history

is provided. Preferably, the structural analysis
includes information related to stresses and
distortions caused by the welding process. This
information may be used to develop methods and

5   techniques to modify the welding process to minimize
the stresses and distortions produced during
subsequent welds.

Other aspects, objects, and features of the
present invention can be obtained from a study of the

10   drawings, the disclosure, and the appended claims.